West Fork White River, Muncie to Hamilton-Marion County Line TMDL for *E. Coli* Bacteria

Data Report

Submitted to:
Indiana Department of Environmental Management
100 N. Senate Avenue
P.O. Box 6015
Indianapolis, IN 46206

Submitted by:
Tetra Tech, Inc.
1468 W. 9th Street
Suite 620
Cleveland, OH 44113

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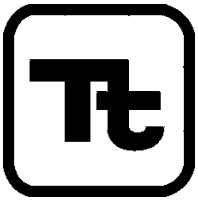

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1.0 INTRODUCTION

The West Fork White River (WFWR) from Muncie to the Hamilton-Marion County line drains approximately 1,100 square miles in central Indiana (Figure 1). Several segments of this stretch of the WFWR appear on Indiana's section 303(d) list of impaired waters for failing to fully support the state's recreation use (Table 1 and Figure 2)[1]. These impairments were identified based on data collected by the Indiana Department of Environmental Management (IDEM) during the 1996 and 2001 water quality surveys which showed violations of the *Escherichia Coli (E. Coli)* standard. *E. Coli* is a bacterium that indicates the presence of human sewage and animal manure. It can enter rivers through direct discharge from mammals and birds, from agricultural and storm runoff carrying mammal wastes (manure), and from sewage leaked into the water. *E. Coli* is also an indication of the possible presence of other disease causing organisms or pathogens.

Table 1. Impaired waterbodies listed for *E. Coli* from the 1998 section 303(d) list in the WFWR watershed above the Hamilton-Marion County line.

Stream Segment	Waterbody ID	Designated Use	Support Status	Sources
West Fork White River (Hamilton and Madison Co)	IN05120201050	Recreation	Impaired	Industrial Point Source Unknown
West Fork White River (Muncie to Anderson)	IN05120201030	Recreation	Impaired	Unknown
Killbuck Creek	IN05120201040	Recreation	Impaired	Unknown
Pipe Creek	IN05120201060	Recreation	Impaired	Unknown
Stoney Creek	NA	Recreation	Impaired	Unknown
Cicero Creek	IN05120201080	Recreation	Impaired	Unknown
Duck Creek	IN05120201070	Recreation	Impaired	Unknown

Sources: IDEM, 1998a; IDEM, 1998b.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for all waters on the section 303(d) lists. A TMDL is the sum of the allowable amount of a single pollutant that a waterbody can receive from all contributing point and nonpoint sources and still support its designated uses. IDEM is in the initial stages of developing *E. Coli* TMDLs for the WFWR above the Hamilton-Marion County line and the overall goals and objectives of the project are to

- Further assess the water quality of the WFWR and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science to determine the maximum load of *E. Coli* that the river can receive and still fully support all of its designated uses.
- Use the best available science to determine current loads of *E. Coli*
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.

[1] Indiana's current section 303(d) list is the one submitted to and approved by USEPA in 1998. A draft 2002 section 303(d) list is currently being reviewed by USEPA.

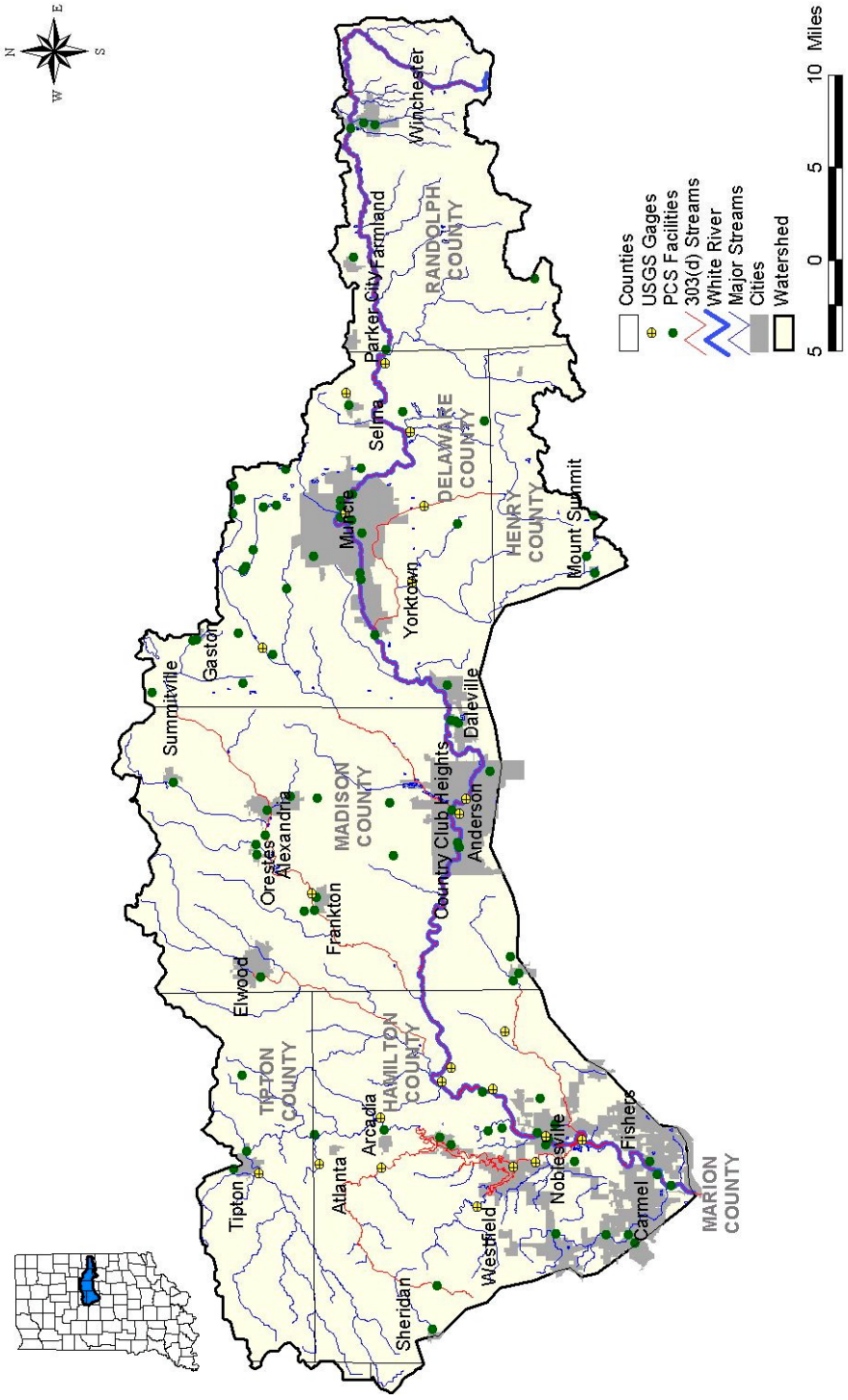

Figure 1. Political map of the WFWR watershed above the Hamilton-Marion County line.

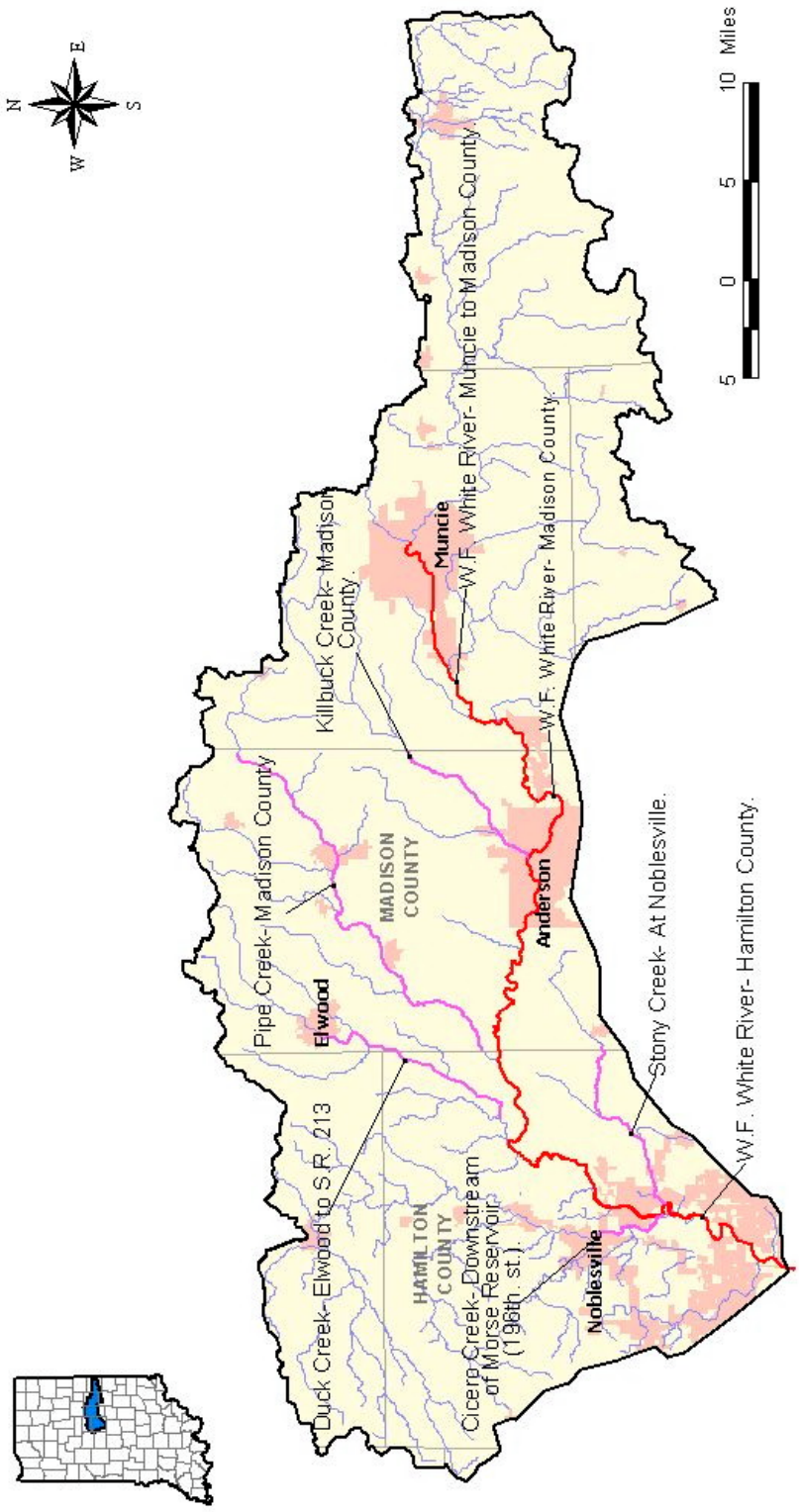

Figure 2. Waters in the WFWR watershed above the Hamilton-Marion County line that are listed for *E. Coli*.

- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

This report provides an inventory of available information that will be used during the development of the TMDL, describes the physical setting of the watershed, and discusses the spatial and temporal extent of *E. Coli* concentrations. The report contains a discussion of the following topics:

- Population
- Topography
- Land uses
- Soils
- Climate and weather
- Hydrology
- Water Quality

Future reports will further identify and assess the sources of *E. Coli*, recommend a modeling approach, present the regulatory elements of the TMDL, and identify implementation activities.

Figure 3. West Fork White River at Minnetrista Cultural Center near Muncie.

2.0 WATERSHED CHARACTERISTICS

The WFWR is located in central Indiana and the segment of interest for this TMDL extends from the City of Muncie to the Hamilton-Marion County line. The watershed associated with this segment is 1160 square miles and encompasses portions of Tipton, Hamilton, Madison, Delaware, Henry and Randolph Counties (Figure 1). The watershed is the upstream portion of the larger Upper White River basin (HUC 05120201).

The sections below provide information on the population, land uses, topography, and climate associated with the watershed. Obtaining an understanding of these issues is a critical first step in developing a TMDL because they provide information on the potential sources of *E. Coli*, as well as characteristics of the watershed that might affect water quality.

2.1 Population

The population of the WFWR watershed above the Hamilton-Marion County line is approximately 200,000 with the majority concentrated in the cities of Anderson, Muncie, Noblesville, Fishers and Carmel (Table 2). Hamilton County is one of the fastest growing counties in the country, with a 68 percent increase in population from 1990 to 2000. The major population center in the watershed is Muncie, with a population of approximately 67,430 people (US Census Bureau, 2000).

Table 2. Population data for cities within the WFWR watershed above the Hamilton-Marion County line. Note that portions of some cities are outside the watershed.

City	County	1990 Population	2000 Population	Percent Change
Anderson	Madison	59,949	59,734	-0.36
Carmel	Hamilton	25,380	37,733	48.67
Elwood	Madison/Tipton	9,490	9,737	2.60
Fishers Town	Hamilton	7,508	37,835	403.93
Muncie	Delaware	71,035	67,430	-5.07
Noblesville	Hamilton	17,655	28,590	61.94
	Totals	191,017	241,059	26.20

Table 3 below provides the 1990 Census information for sewage disposal methods for households in the five counties that overlap the watershed. Similar information is not available for the 2000 Census. Sewage disposal information is important to this study because combined sewer overflows, failing septic systems, and illicitly connected septic systems are important potential sources of *E. Coli*. Approximately 70 percent of the households in the area are on public sewer and 30 percent use septic systems. More detailed information on sewered and unsewered areas of the watershed have been requested of the county health departments. Once this information is received it will be used to estimate the extent to which failing or illicitly connected septic systems contribute to the *E. Coli* impairment.

Table 3. Methods of sewage disposal for households in the counties that overlap the watershed.

County	Number of Housing Units	Public Sewer	Septic Tank or Cesspool	Other Means
Delaware	48,793	37,832	10,676	285
Hamilton	41,074	29,259	11,716	99
Henry	19,835	11,201	8,524	110
Madison	53,353	37,203	15,914	236
Randolph	11,327	6,132	5,057	138
Tipton	6,427	2,839	3,494	94
Totals	180,809	124,466	55,381	962

2.2 Topography

The WFWR watershed above the Hamilton-Marion County line lies in the Tipton Till Plain, a physiographic region characterized by flat to gently rolling terrain. Topography in the watershed is a result of continental glaciation during the most recent ice age. Figure 4 presents the general topography within the watershed. Elevation ranges from 734 feet at the Hamilton-Marion County line to more than 1200 feet in the headwaters (USGS, 1993). The average slope in the watershed is 1.0 percent (calculated by measuring the average slope of each 100 foot by 100 foot parcel of land in the watershed).

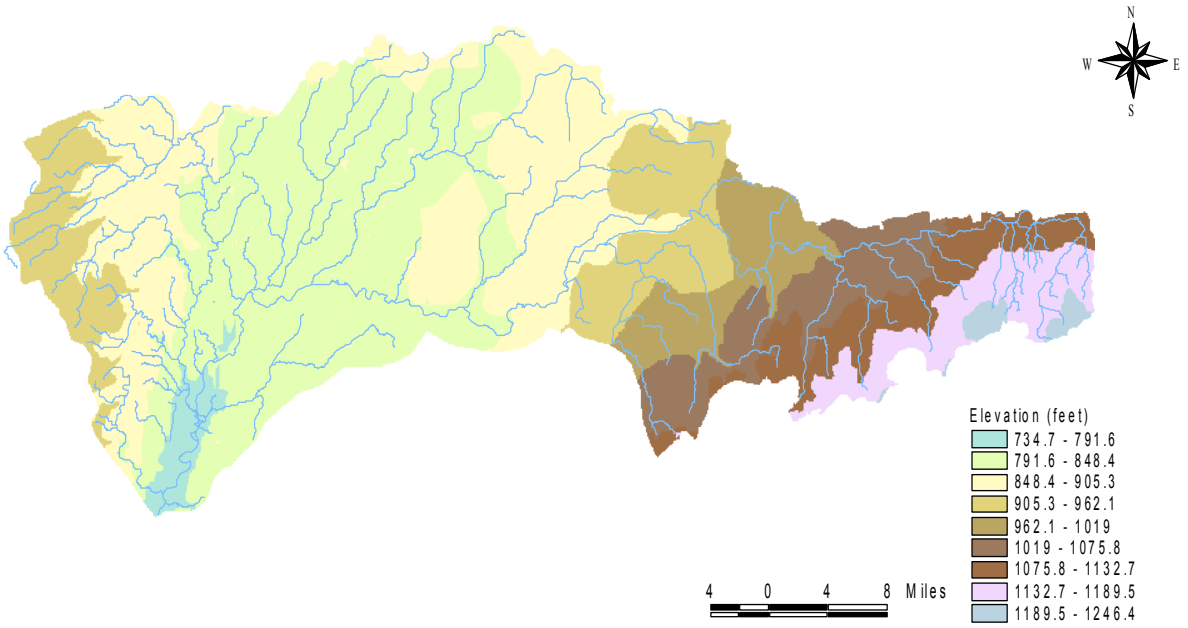

Figure 4. Topography of the Upper White River watershed.

2.3 Land Use

Land use information for the WFWR watershed above the Hamilton-Marion County line is available from the Multi-Resolution Land Characteristics Consortium (MRLC). The land use data are derived from images acquired by Landsat's Thematic Mapper satellite during the early 1990s. These data categorize the land use for each 100 foot by 100 foot parcel of land in the watershed.

Table 4 provides a breakdown of the land uses in the watershed and Figure 6 displays the spatial distribution of the land uses. The watershed is mostly row crop agriculture with areas of low density residential lands concentrated around the cites of Muncie, Anderson, and Indianapolis. It should be pointed out that since the MRLC data are based on satellite imagery from the early 1990s, land uses in some parts of the watershed have undoubtedly changed. This is especially true of the area near Carmel and Fishers. Estimates of the extent of such change will be made using the population data presented above and the recommendations of local government officials. These updated estimates will be used for development of the TMDL.

Figure 5. Row crop agriculture and buffer strip adjacent to WFWR between Muncie and Anderson.

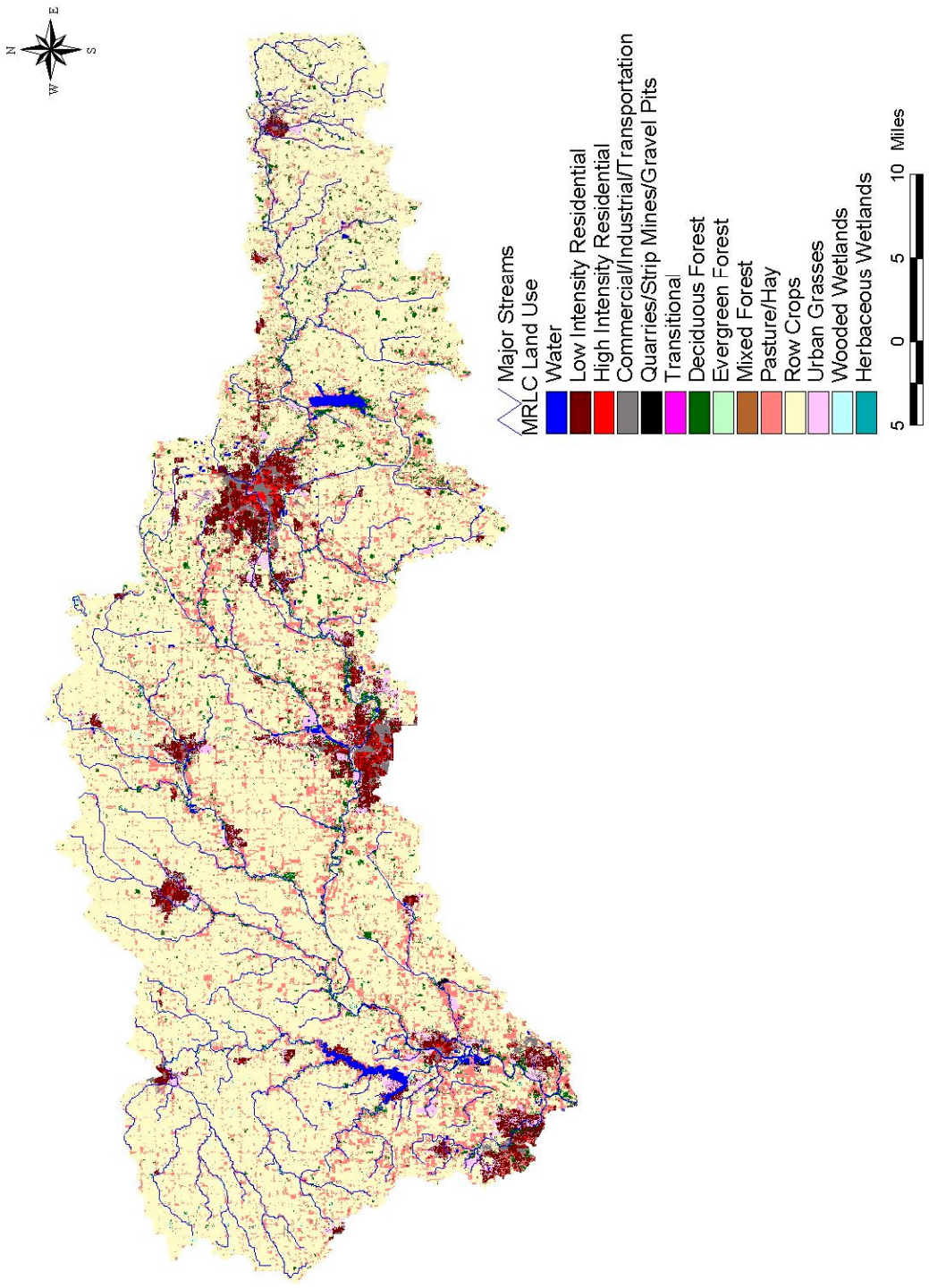

Figure 6. Land use in the WFWR watershed above the Hamilton-Marion County line.

Table 4. Land use distribution in the WFWR watershed above the Hamilton-Marion County line.

Land Use	Area (acres)	Percent (%)
Row Crops	540,650	72.80
Pasture/Hay	99,487	13.40
Low Intensity Residential	30,685	4.13
Deciduous Forest	30,079	4.05
Other Grasses	14,606	1.97
High Intensity Commercial	9,138	1.23
Woody Wetlands	8,387	1.13
Open Water	5,184	0.70
High Intensity Residential	3,475	0.47
Emergent Herbaceous Wetlands	474	0.06
Quarries/Strip Mines/Gravel Pits	310	0.04
Evergreen Forest	155	0.02
Mixed Forest	25	0.00
Total	**742,655**	**100**

Source: MRLC, 2000.

2.4 Soils

Soils data from the Natural Resources Conservation Service (NRCS) were used to characterize soils in the watershed. General soils data and map unit delineations are available through the State Soil Geographic (STATSGO) database. GIS coverages provide accurate locations for the soil map units at a scale of 1:250000 (USDA, 2002). A map unit is composed of several soil series having similar properties. Identification fields in the GIS coverages can be linked to a database that provides information on chemical and physical soil characteristics, which can in turn be used in setting up and calibrating a watershed model.

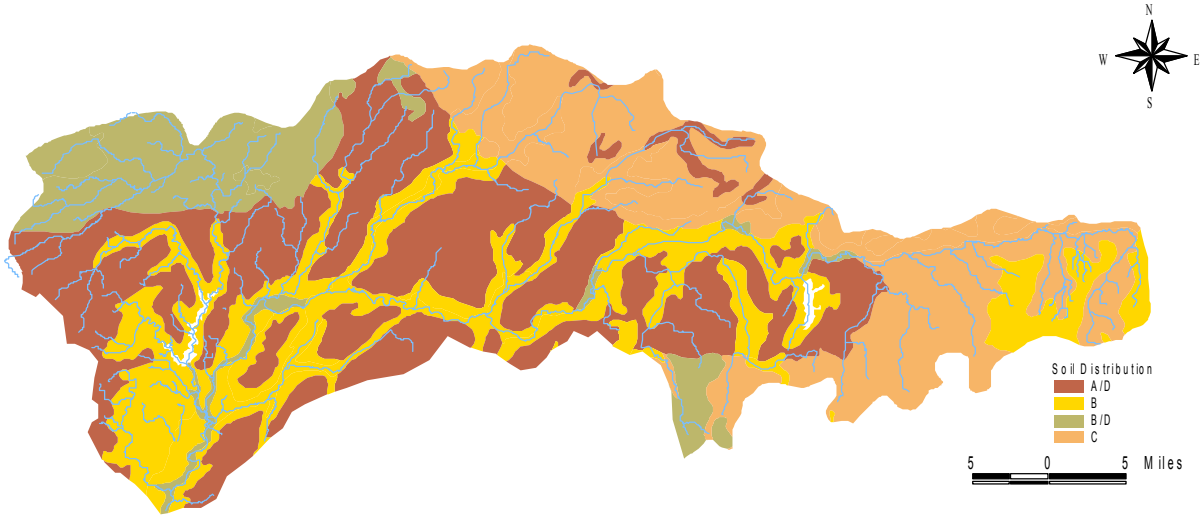

Figure 7. Hydrologic soil groups in the White River watershed.

The hydrologic soil group classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have lower infiltration rates, while sandy soils that are well drained have the greatest infiltration rates. NRCS has defined four hydrologic groups for soils (Table 5). The corresponding spatial distribution of hydrologic soil groups in the WFWR watershed is illustrated in Figure 7. The upstream portion of the watershed consists of moderately drained soils with low organic content. The downstream portion of the watershed consists of well drained sandy and silty soils Note that the A/D and B/D classifications in Figure 7 indicate soils that are well drained when dry but poorly drained when wet.

Table 5. Characteristics of hydrologic soil groups.

Soil Group	Characteristics	Minimum Infiltration Capacity (inches/hour)
A	Sandy, deep, well drained soils; deep loess; aggregated silty soils	0.30-0.45
B	Sandy loams, shallow loess, moderately deep and moderately well drained soils	0.15-0.30
C	Clay loam soils, shallow sandy loams with a low permeability horizon impeding drainage (soils with a high clay content), soils low in organic content	0.05-0.15
D	Heavy clay soils with swelling potential (heavy plastic clays), water-logged soils, certain saline soils, or shallow soils over an impermeable layer	0.00-0.05

Source: NRCS, 1972

3.0 CLIMATE AND HYDROLOGY

3.1 Climate

The WFWR watershed has a climate characterized by warm summers and cool winters. Temperatures range from around 26 degrees in January to 74 degrees in July (MRCC, 2002). Several National Climatic Data Center (NCDC) gages are located in or near the watershed. These stations record climatic variables such as temperature, precipitation, wind speed and potential evapotranspiration. The closest stations are at the Richmond Water Works (station 93815) and the Indianapolis Airport (station 93819). Several additional stations within the watershed have data for only precipitation and temperature. These include Farmland 5 (station IN2825), the Anderson Sewage Treatment Plant (station IN0177) and Tipton 5 SW (station IN8784). Figure 8 shows the locations of these climate and precipitation stations.

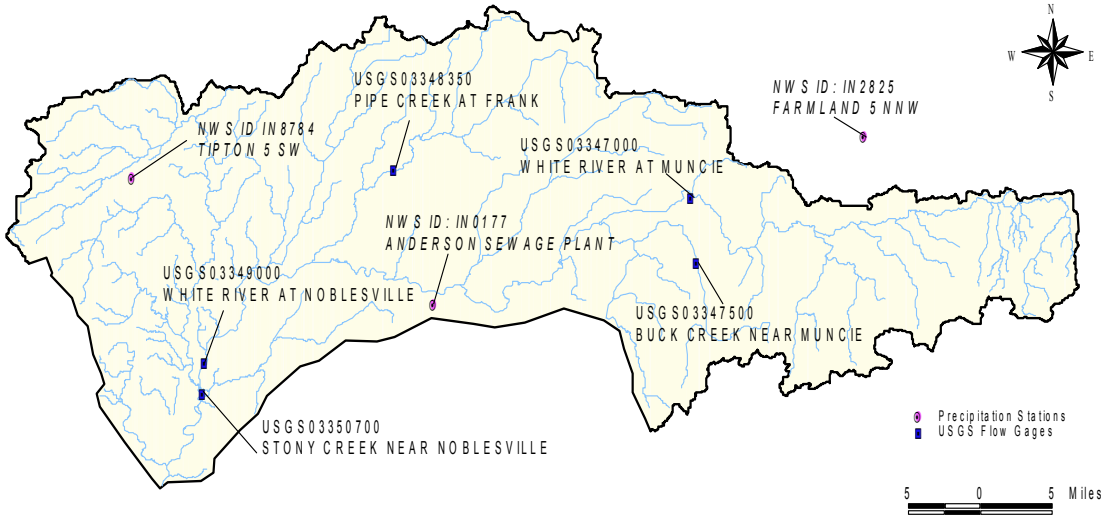

Figure 8. Location of precipitation and stream flow stations in the White River watershed.

During a ten year period between 1990 and 2000, the average annual precipitation in the watershed was approximately 40.6 inches with a maximum in 1990 of 58.6 inches and a minimum of 28.5 inches in 1999. The mean annual number of days when precipitation exceeds 0.10 inch is about 75 days. Figure 9 presents a comparison of annual precipitation data for several stations in the WFWR watershed.

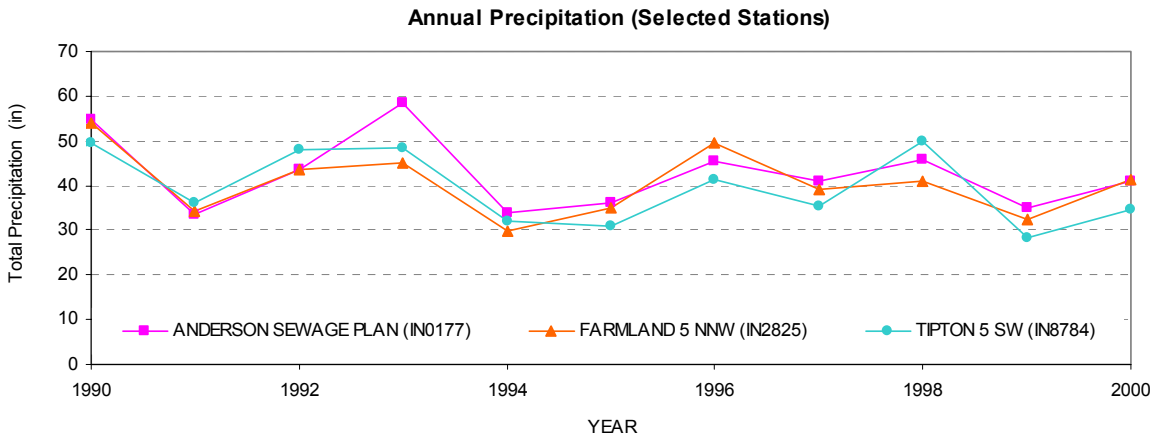

Figure 9. Annual precipitation at White River watershed stations.

3.2 Hydrology

The U. S. Geological Survey (USGS) has five active stream flow stations in the WFWR watershed above the Hamilton-Marion County line. Several other stations in the watershed stopped recording flow during the 1990s (White River at Anderson, Killbuck Creek near Gaston, Cicero Creek at Noblesville). The locations of the active stations are presented in Figure 8 and the period of record information for these stations is presented in Table 6.

The flow data spans several years that overlap with the available climate information. This provides a good hydrologic picture of the watershed. Furthermore, the USGS gages monitor flow for a range of drainage areas—from small subwatersheds (36 square miles) up to nearly the entire watershed (858 square miles). Having information for various sized drainage areas will be useful in the modeling effort. Hydrographs for the stations are presented in Figure 10. The hydrographs for each gage are similar and show that flows are typically the greatest in March and April during spring rains and snowmelt and lowest in the late summer and early fall.

Table 6. Active USGS Stations in the WFWR watershed.

Station ID	Station Name	Start Date	End Date	Drainage Area (sq. miles)
03347000	White River at Muncie	4/1/1931	Present	241
03347500	Buck Creek near Muncie	10/1/1954	Present	36
03348350	Pipe Creek at Frankton	5/1/1968	Present	113
03350700	Stony Creek Near Noblesville	6/27/1967	Present	51
03349000	White River at Noblesville	10/1/1946	Present	858

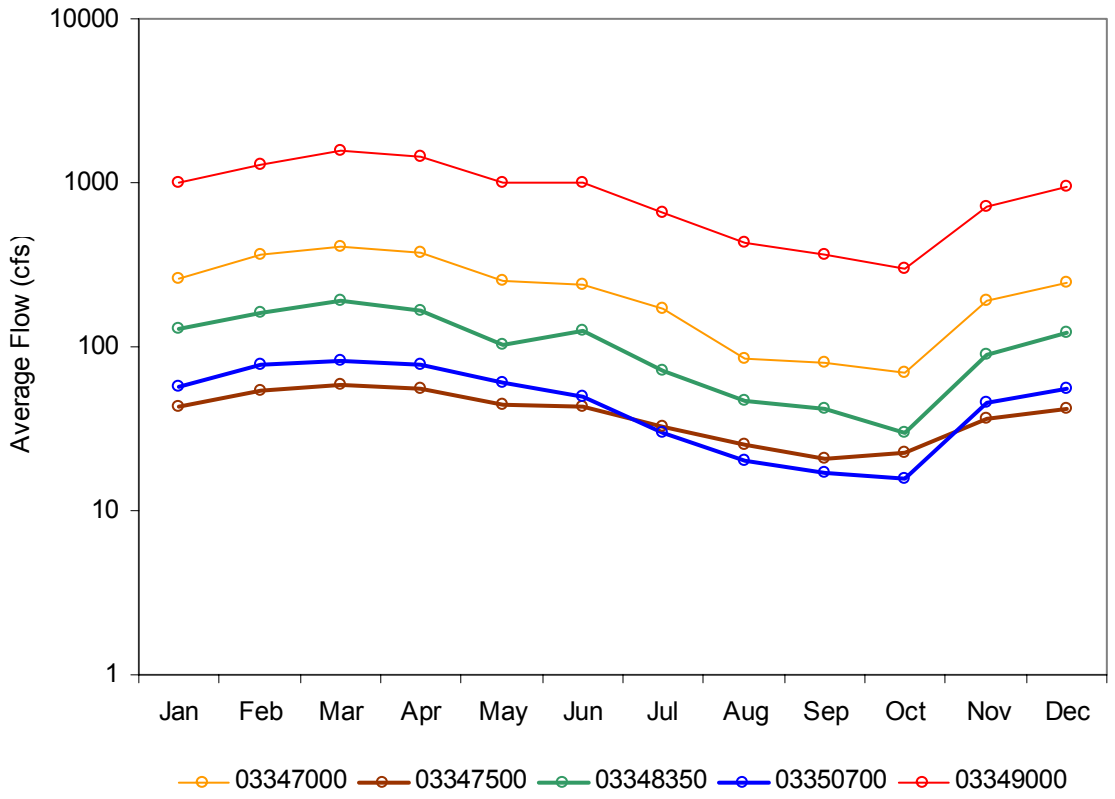

Figure 10. Average monthly flows in the WFWR watershed above the Hamilton-Marion County line.

4.0 INVENTORY AND ASSESSMENT OF WATER QUALITY INFORMATION

IDEM monitors the presence of *E. Coli* under the Surface Water Quality Assessment program. The state has adopted a rotating basin approach to water quality planning, monitoring, assessment, reporting, protection and restoration. This rotating basin approach to watershed management began in 1996. The Upper West Fork of the White River watershed was one of the first monitored under the current program. Therefore the WFWR watershed above the Hamilton-Marion County line was monitored and assessed in 1996 and then again in 2001. The monitoring strategy is designed to describe the overall environmental quality of each major river basin and to identify which water bodies do not meet water quality standards.

Figure 11. IDEM sampling station at Jackson Street bridge in Muncie.

IDEM has sampled water quality data for 146 monitoring stations in the WFWR watershed above the Hamilton-Marion County line. The database contains more than 14,834 records for approximately 50 different parameters (e.g., dissolved oxygen, pH, phosphorus, nitrogen, total suspended solids). The data cover a period from 1991 to 2001 and therefore include the 1996 and 2001 assessments that were done in support of IDEM's 303(d) listing. Figure 12 presents the locations of surface water quality stations in the watershed, including the four stations with the most data.

IDEM has identified three segments of the WFWR and five tributaries as impaired and listed on Indiana's 1998 section 303(d) list for violations of the *E. Coli* water quality standards. Several parameters were sampled to address the pathogen impairment. These include *E. Coli*, fecal coliform, temperature, pH and turbidity. Appendix A presents a summary of the *E. Coli* data for all the stations in the watershed and the sections below present the results of a spatial and temporal analysis of the data.

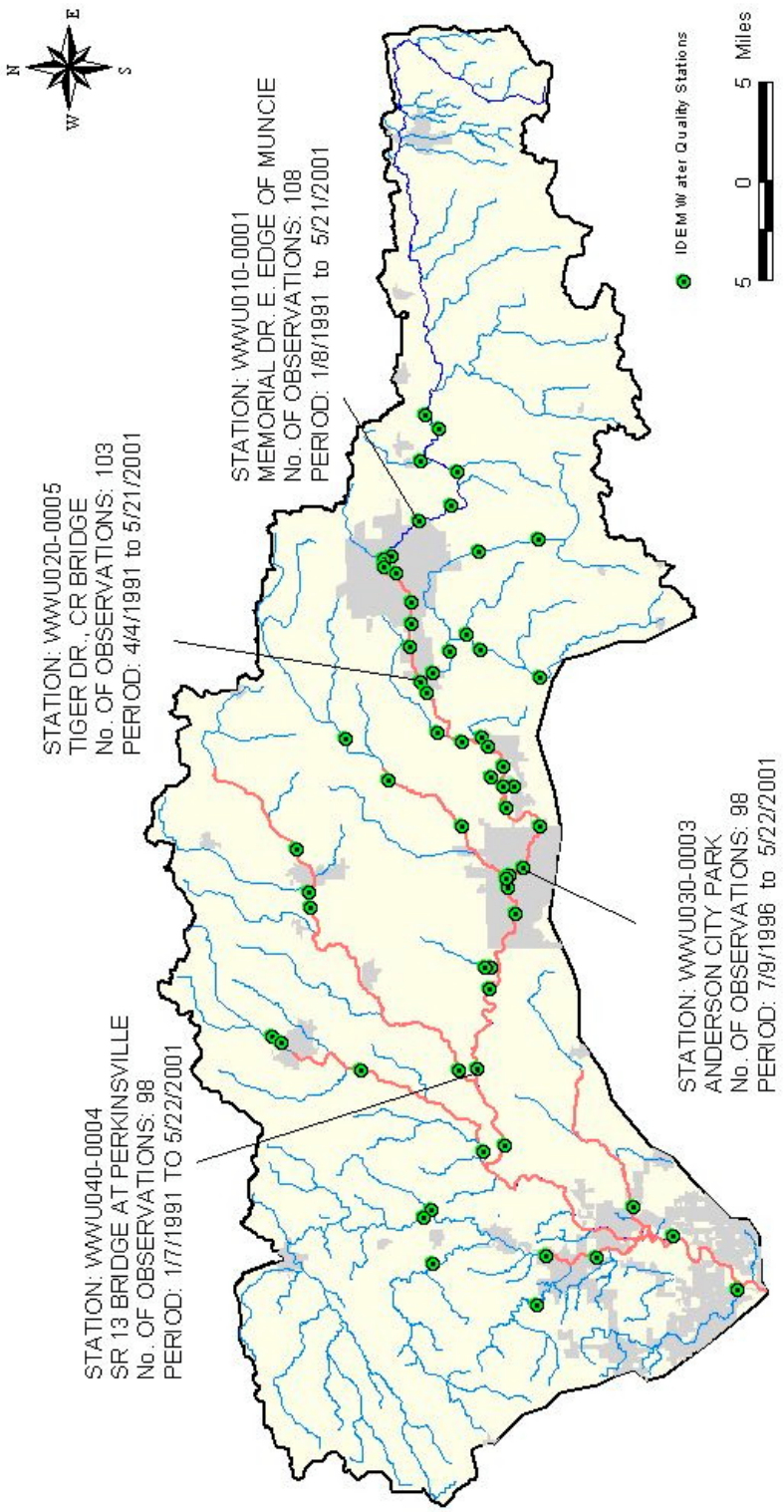

Figure 12. Location of IDEM surface water quality monitoring stations and identification of sites with the most data.

4.1 Adherence to QA/QC

Development of a TMDL requires that rigorous data screening procedures be conducted to ensure the accuracy of the information used to determine existing loads and, ultimately, the necessary load reductions. IDEM has established the following guidelines for determining the acceptability of data:

- The data have been collected and analyzed using QA/QC procedures contained in the State's QA/QC plan entitled "Quality Assurance Project Plan for Indiana Surface Water Quality Monitoring Programs;" or

- The data have been collected and analyzed using QA/QC procedures other than those contained in the State's QA/QC plan that are:

    i. comparable to the QA/QC procedures contained in the State's QA/QC plan; and
    ii. approved, in writing, by the State; or

- The data have otherwise been validated and accepted by the State.

All of the water quality data described in this section of the Data Report met the first guideline because the data were collected by IDEM in accordance with the "Quality Assurance Project Plan for Indiana Surface Water Quality Monitoring Programs". Additional water quality data have been requested from different entities and these data will be assessed for their acceptability once they are received. The testing method for *E. Coli* is a significant factor in deciding whether data meet quality objectives. IDEM accepts *E. Coli* data collected using both the Membrane Filter Method and the Colilert Quantitray methods because these methods are comparable in accuracy and reliability. The Coliscan Easygel test is not approved by IDEM for enumerating *E.Coli* for NPDES reporting. However, it is considered acceptable for water monitoring programs because it has been approved by EPA.

4.2 Confirmation of Impairment and its Extent

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three different components:

- **Designated uses** reflect how the water can potentially be used by humans and how well it supports a biological community. Examples of designated uses include aquatic life support, drinking water supply, and recreation. Every water in Indiana has a designated use or uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support the designated uses. **Numeric criteria** represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. **Narrative criteria** are the general water quality criteria that apply to all surface waters. These criteria state that all waters must be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that may cause algal blooms
- The **antidegradation policy** establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to

> demonstrate an important social or economic need. This policy only applies to surface water within the Great Lakes system.

All water bodies in Indiana are designated for recreational use. The numeric criteria associated with protecting the recreational use are described below.

> "This subsection establishes bacteriological quality for recreational uses. In addition to subsection (a), the criteria in this subsection are to be used to evaluate waters for full body contact recreational uses, to establish wastewater treatment requirements, and to establish effluent limits during the recreational season, which is defined as the months of April through October, inclusive. *E. Coli* bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period." [Source: Indiana Administrative Code Title 327 Water Pollution Control Board. Last Updated October 1, 2002]

The Muncie to Hamilton-Marion County line segment of the WFWR has been listed as impaired for violations of the *E. Coli* criteria. The sections below discuss the nature of this impairment.

4.2.1 Comparison to Geometric Mean Standard

The geometric mean portion of the standard requires that five samples be collected during a 30 day period. Historically, not all sampling has been conducted at this frequency. However, sampling during the 2001 assessment was done at the necessary frequency and the spatial distribution of violations to the standard is presented in Figure 13. The violations of the geometric mean standard confirm the impairment of the WFWR from Muncie through Madison County and into Hamilton County. Of the 29 stations with suitable data to compare to the standard, all but four exhibited at least one violation of the standard. The station near Daleville had six violations of the standard.

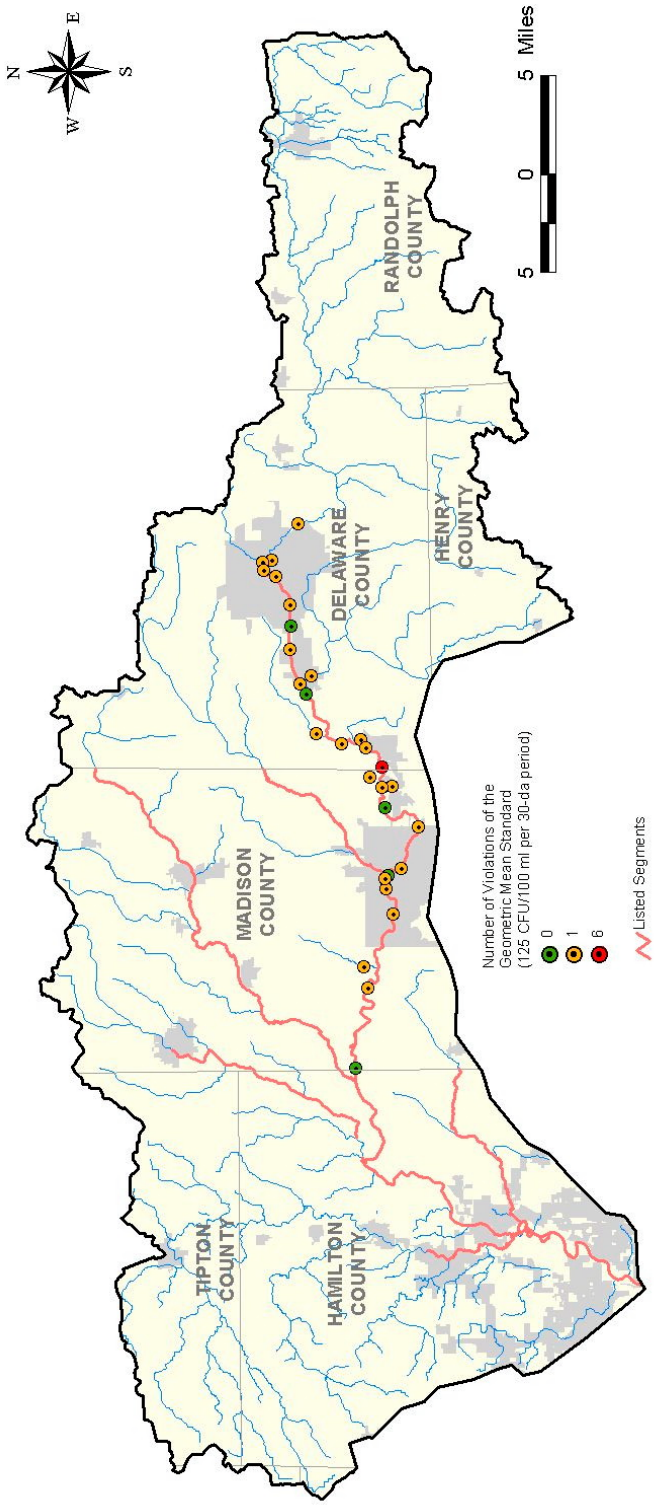

Figure 13. Violations of the Geometric Mean Standard at IDEM stations with sufficient data to make a comparison.

4.2.2 Comparison to the Never Exceed Standard

The never exceed standard applies to all grab samples collected during the recreational season. Figure 14 presents the spatial distribution of violations to the standard within the watershed. All but seven stations exhibited at least one violation of the standard, with percentages ranging from 0 to 100 percent of samples collected. Conditions appear to be similar throughout the watershed, with both mainstem and tributary stations showing violations. All stations in the segment between Muncie and Anderson had at least one violation of the standard.

The frequency of violations at stations with a significant amount of data (more than 10 samples) was evaluated to provide a more comprehensive view of the extent of impairments. Table 7 identifies the four stations with the most observations. For these stations the frequency of violations ranges from 43 percent at the most upstream site to 69 percent of samples at the Tiger Drive station, just west of Muncie.

Table 7. Violations of the never exceed standard for selected stations.

Station	Location	Total Observations	Number Of Violations	Frequency of Violations (percent)
WWU040-0004	SR 13 Bridge at Perkinsville	98	50	51.0
WWU020-0005	Tiger Dr, CR Bridge N of Yorktown HS	103	71	69.0
WWU030-0003	Anderson City Park Near Old Water Works Dam Site	104	56	53.8
WWU010-0001	Memorial Dr, E Edge of Muncie	108	47	43.5

The seasonal variation of *E. Coli* concentrations can also be explored. Data from station WWU020-0005 (west of Muncie) were used to calculate monthly means for the data period 1991 through 2001. These means and respective error statistics are plotted in Figure 15 and indicate that all means for this station violate the "never-exceed" standard, with the highest concentrations occurring in May and the lowest in June. Figures 16 to 19 show similar data for other stations in the watershed.

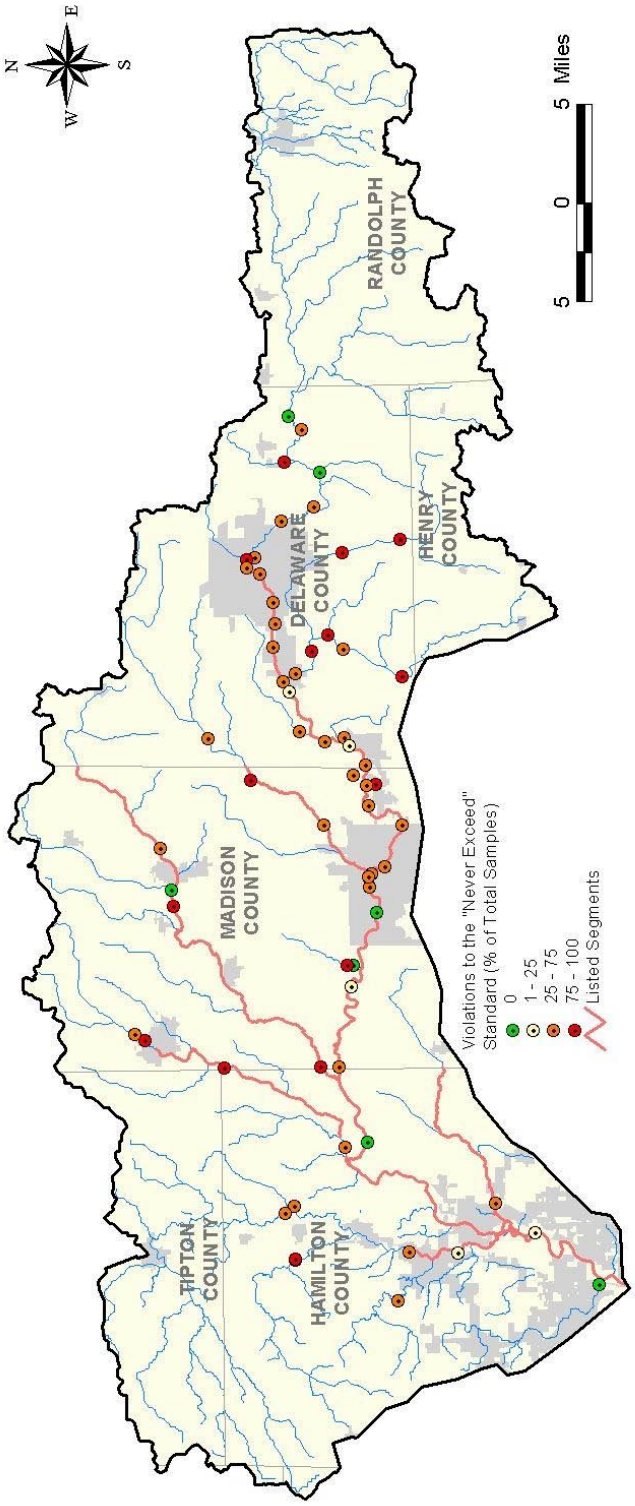

Figure 14. Violations of the never exceed standard

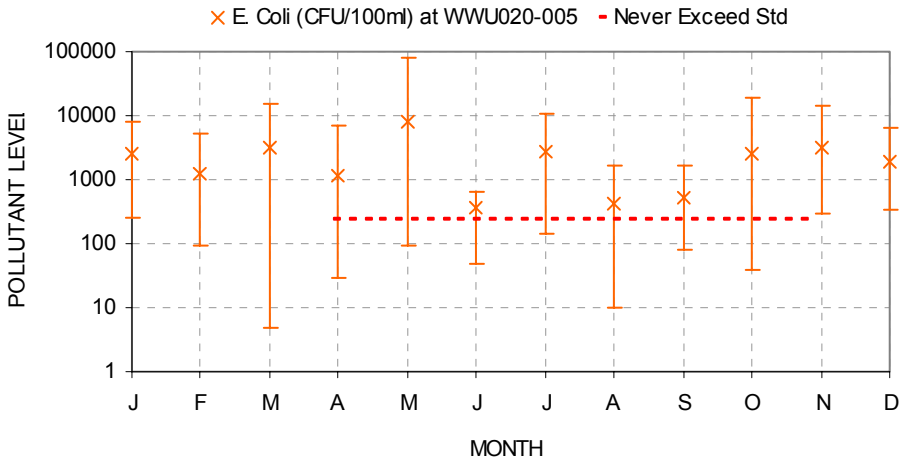

Figure 15. Minimum, maximum, and average *E. Coli* concentrations for station WWU020-0005.

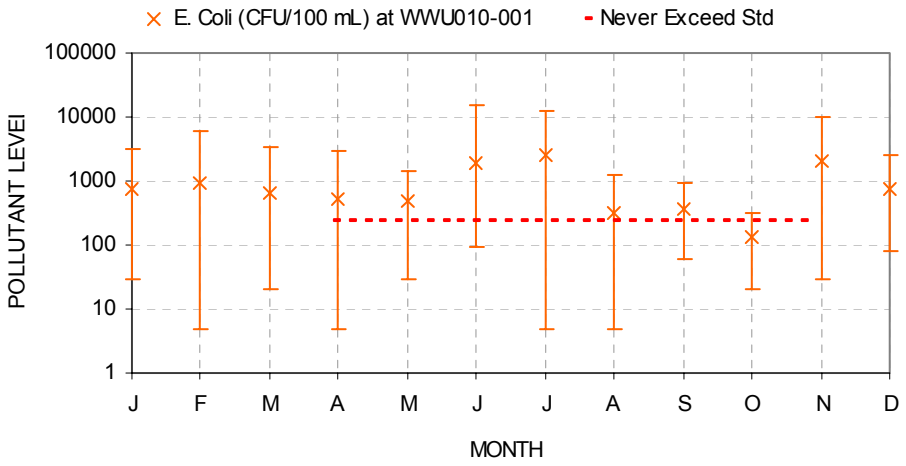

Figure 16. Minimum, maximum, and average *E. Coli* concentrations for station WWU010-0001

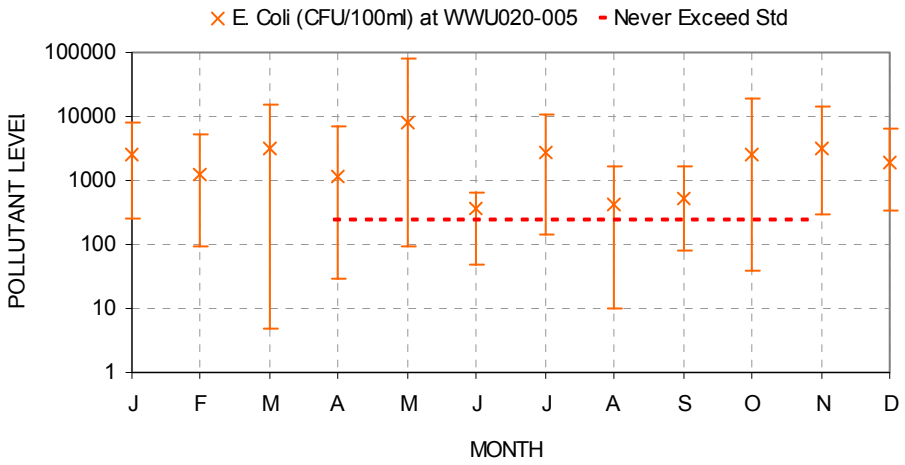

Figure 17. Minimum, maximum, and average *E. Coli* concentrations for station WWU020-0002.

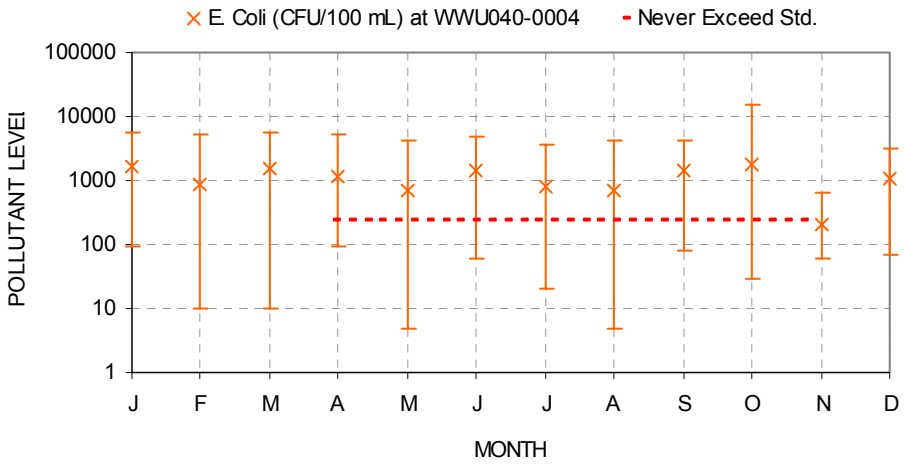

Figure 18. Minimum, maximum, and average *E. Coli* concentrations for station WWU040-0004.

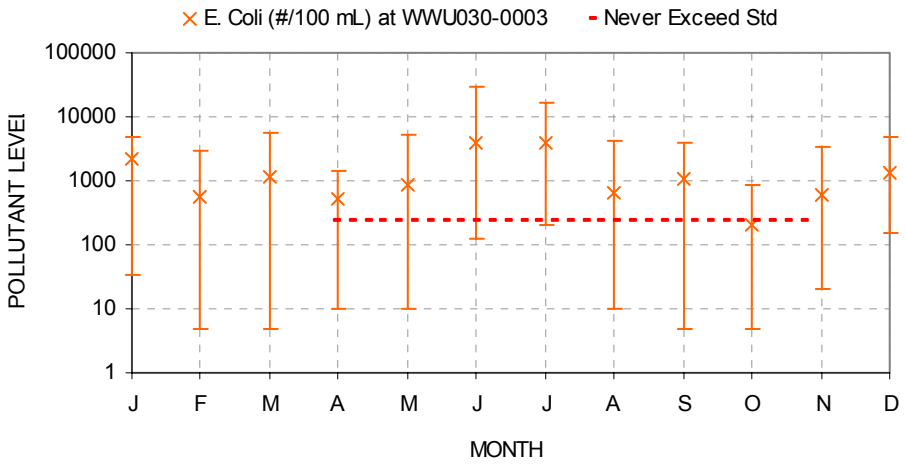

Figure 19. Minimum, maximum, and average *E. Coli* concentrations for station WWU030-0003

The comparisons of water quality data against the "never exceed" standard show widespread (both in terms of geography and season) violations. Therefore the analysis verifies impairment of the WFWR through Madison and Hamilton Counties.

4.3 Analysis of the Influence of Weather

Analyzing water quality data for the influence of weather can provide important information regarding potential sources of pathogens. For example, if high concentrations of *E. Coli* are only found during wet weather events, nonpoint sources such as combined sewer overflows might be a significant source. In contrast, if *E. Coli* concentrations are high only during dry weather periods some constant source, such as wildlife or failing septic systems, are likely dominant.

The water quality station at Tiger Drive Bridge north of Yorktown High School was examined to evaluate the effects of weather on *E. Coli* concentrations. The USGS gage at Muncie (USGS 003347000), approximately 5 miles downstream of the water quality station, was used to investigate the correlation between flow and *E. Coli* concentrations.

Figure 20 presents a statistical comparison of flow percentile range and mean observed concentrations for the entire data record. The maximum observed concentration (80,000 cfu/ml) falls in the 60 to 70 percentile flow range. However, the second highest *E. Coli* concentration (19,000 cfu/ml) occurred at the low flow end of the percentile range (10 to 20 percentile).

If a strong correlation between flow rates and *E. Coli* concentrations existed, it would be expected that high *E. Coli* concentrations would consistently fall within the higher flow percentiles, and low concentrations would occur at lower flows. However, preliminary analysis of the data at station WWU20-0005 suggests that this is not the case and that there is not a strong correlation between flow and *E. Coli* concentrations at this station. This implies that sources associated with both constant and wet weather discharges are contributing to the impairment.

Similarly a strong correlation with flow would have *E. Coli* concentrations varying seasonally in the same manner as flow. Figure 21 presents this comparison for the Tiger Drive station. Although the correlation is not striking, concentrations of *E. Coli* can be seen to vary seasonally in a manner that somewhat

parallels flow. Figures 22 to 25 display the same data for other stations in the watershed and the results are similar.

Location: White River Tiger Dr, CR Bridge N of Yorktown HS (Station Id WWU20-0005)
Pollutant: E. Coli (cfu/100ml)
Data from: 4/4/1991 to 5/21/2001 (103 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	12	14.417	6.300	18.000	682	50	6500
10-20	9	21.778	19.000	25.000	4179	50	19000
20-30	10	33.500	26.000	40.000	1137	40	3500
30-40	10	46.500	40.000	53.000	706	10	4900
40-50	11	78.545	58.000	91.000	896	50	3800
50-60	10	101.800	93.000	117.000	1581	5	14000
60-70	10	146.300	118.000	190.000	9162	30	80000
70-80	10	218.600	194.000	247.000	1088	30	7100
80-90	10	379.700	250.000	511.000	3568	180	15000
90-100	11	1359.455	587.000	3720.000	4173	480	11000

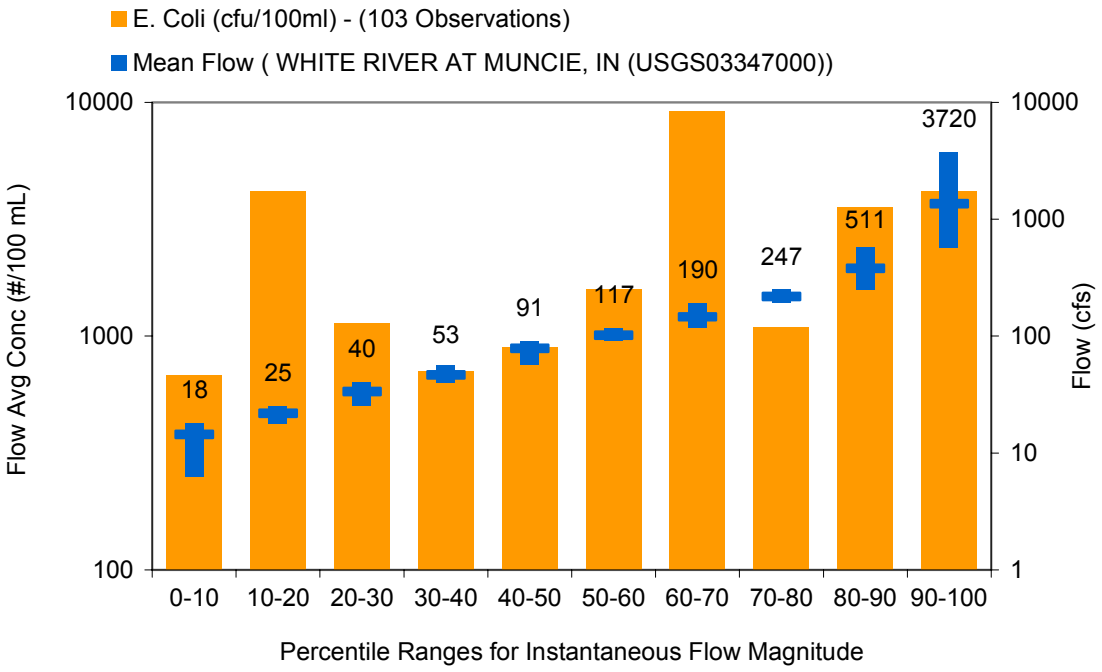

Figure 20. Analysis of the effect of flows on *E. Coli* concentrations for station WWU20-0005 (Tiger Dr. Bridge, near Muncie).

Location: White River Tiger Dr, CR Bridge N of Yorktown HS (Station Id WWU20-0005)
Pollutant: E. Coli (cfu/100ml)
Data from: 4/4/1991 to 5/21/2001 (103 Observations)

Time Period	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	8	919.250	15.000	3720.000	4261	260	8300
February	8	210.000	78.000	474.000	1857	90	5100
March	7	324.857	93.000	647.000	4929	5	15000
April	10	443.900	104.000	1990.000	1671	30	7100
May	12	331.167	80.000	898.000	4741	90	80000
June	7	117.143	32.000	247.000	472	50	650
July	10	241.300	21.000	1500.000	7358	140	11000
August	8	27.625	12.000	53.000	419	10	1700
September	9	28.700	6.300	75.000	481	80	1600
October	9	29.778	14.000	52.000	2207	40	19000
November	8	64.500	19.000	165.000	3796	300	14000
December	7	176.243	9.700	722.000	2370	340	6500

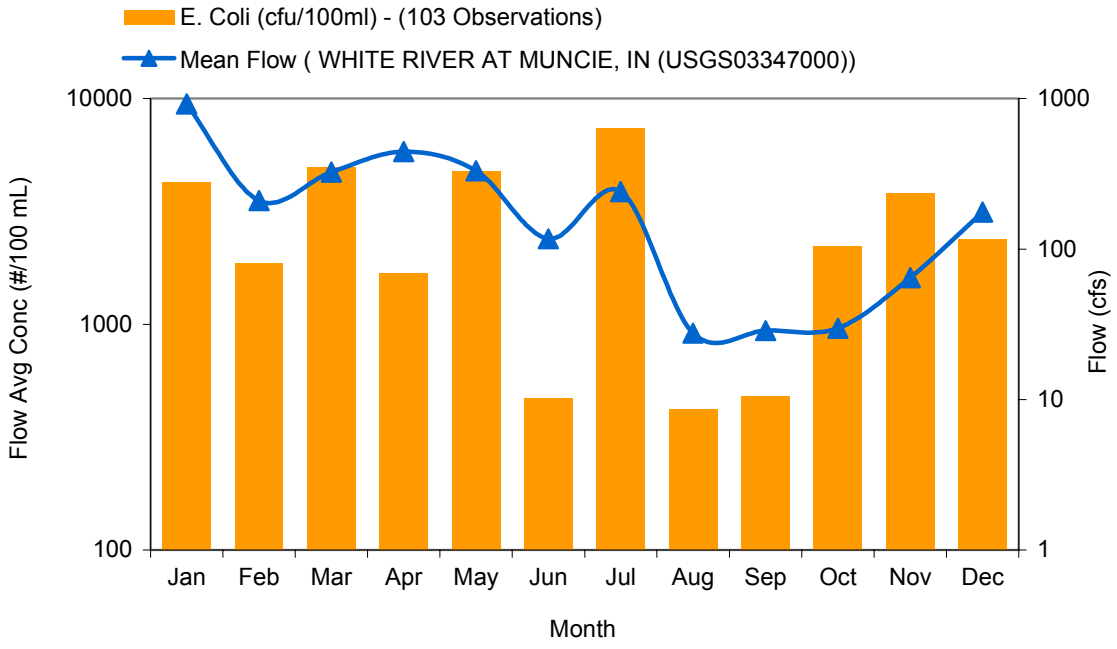

Figure 21. Comparison of seasonal variation of flow and *E. Coli* concentration for station WWU20-0005 (Tiger Dr. Bridge, near Muncie).

Location: White River, Memorial Dr, E Edge of Muncie (Station ID WWU010-001)
Pollutant: E Coli (cfu/100ML)
Data from: 1/8/1991 to 3/30/2000 (103 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	12	15.275	6.300	19.000	229	5	520
10-20	9	22.778	20.000	27.000	428	30	1700
20-30	10	34.900	29.000	40.000	161	80	230
30-40	10	48.200	42.000	53.000	1825	5	10000
40-50	11	79.364	58.000	93.000	200	30	1200
50-60	10	116.800	94.000	135.000	108	5	300
60-70	10	186.700	141.000	216.000	437	30	2500
70-80	10	252.800	223.000	317.000	965	5	5500
80-90	10	450.700	318.000	647.000	1148	80	6200
90-100	11	1330.000	701.000	2500.000	4226	320	15000

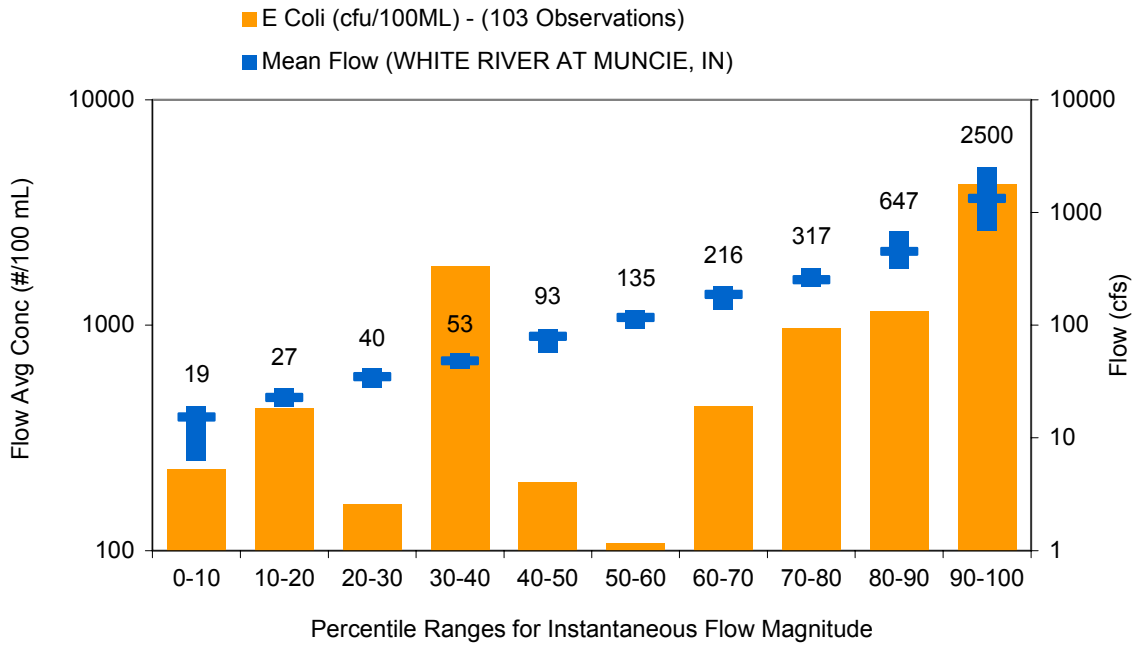

Figure 22. Analysis of the effect of flows on *E. Coli* concentrations for station WWU010-0001 (Memorial Dr., E. Edge of Muncie).

Location: White River, Memorial Dr, E Edge of Muncie (Station ID WWU010-001)
Pollutant: E Coli (cfu/100ML)
Data from: 1/8/1991 to 3/30/2000 (103 Observations)

Time Period	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	7	566.143	15.000	2500.000	2105	30	3100
February	9	201.111	78.000	474.000	1915	5	6200
March	9	449.222	93.000	1270.000	1384	20	3500
April	8	522.125	194.000	1990.000	1720	5	3000
May	11	340.091	80.000	898.000	1515	30	4000
June	9	243.667	32.000	1150.000	8062	90	15000
July	8	257.125	21.000	1500.000	9606	5	12000
August	8	30.625	12.000	68.000	449	5	1200
September	9	28.922	6.300	75.000	340	60	900
October	9	29.778	14.000	52.000	116	20	320
November	9	307.667	19.000	2210.000	654	30	10000
December	7	180.857	24.000	722.000	1489	80	2500

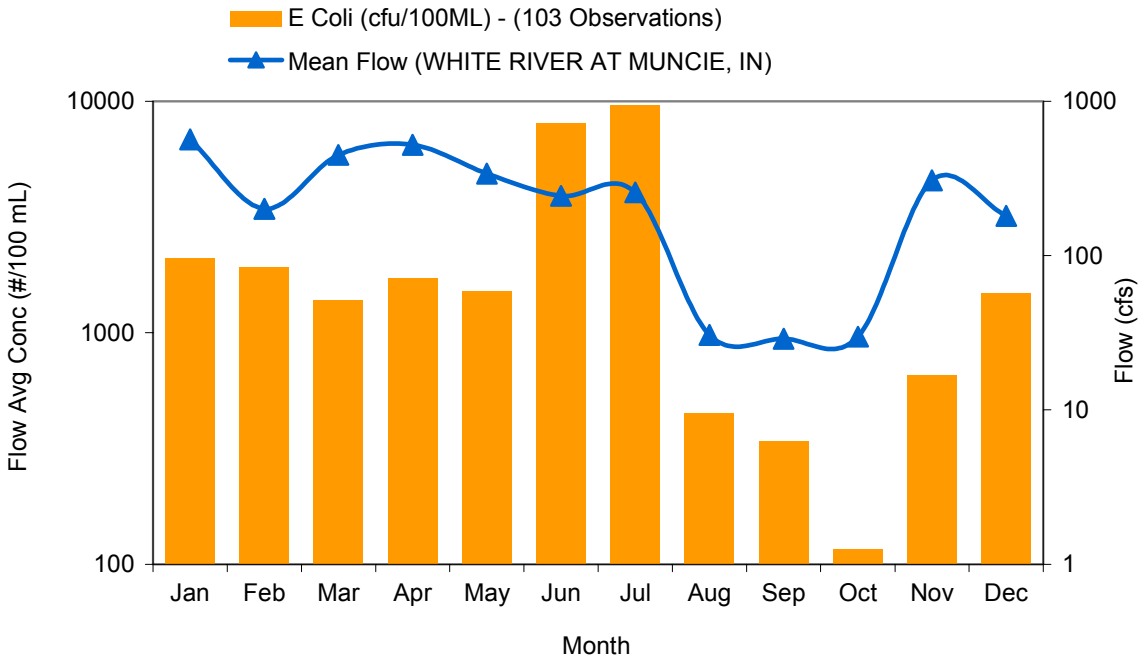

Figure 23. Comparison of seasonal variation of flow and E. Coli concentration for station WWU010-0001 (Memorial Dr., E. Edge of Muncie).

Location: White River, SR 13 Bridge at Perkinsville (Station Id WWU040-0004)
Pollutant: E. Coli (cfu/100ml)
Data from: 1/7/1991 to 5/22/2001 (102 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	11	93.182	16.000	135.000	544	0	4200
10-20	10	157.700	137.000	172.000	772	30	4100
20-30	10	203.000	173.000	239.000	1643	60	15000
30-40	11	300.727	248.000	332.000	267	20	2100
40-50	9	369.556	337.000	427.000	175	5	760
50-60	10	507.500	447.000	541.000	374	0	2400
60-70	10	644.000	553.000	748.000	1394	98	4800
70-80	10	1017.900	756.000	1330.000	507	90	1350
80-90	10	1699.000	1370.000	2640.000	1350	50	3300
90-100	11	4620.000	2720.000	8490.000	3743	640	5700

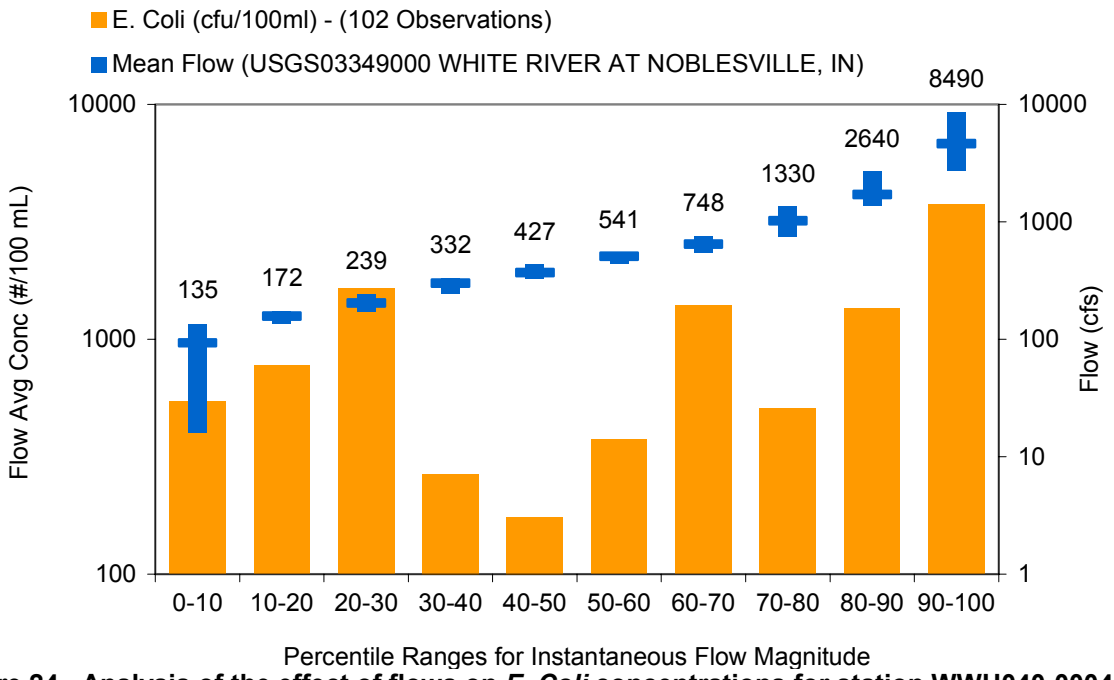

Figure 24. Analysis of the effect of flows on *E. Coli* concentrations for station WWU040-0004 (SR 13 Bridge at Perkinsville).

Location: White River, SR 13 Bridge at Perkinsville (Station Id WWU040-0004)
Pollutant: E. Coli (cfu/100ml)
Data from: 1/7/1991 to 5/22/2001 (102 Observations)

Time Period	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	8	2456.500	332.000	8490.000	4036	90	5700
February	8	988.625	323.000	3970.000	2748	10	5200
March	9	1300.222	84.000	3510.000	2887	0	5600
April	9	2000.889	614.000	5640.000	2249	90	5200
May	14	1225.143	316.000	3840.000	1385	0	4300
June	7	1168.286	312.000	3120.000	1877	60	4800
July	6	345.833	171.000	748.000	1463	20	3700
August	7	199.000	150.000	340.000	588	5	4100
September	11	175.545	16.000	473.000	1364	0	4200
October	9	171.667	87.000	369.000	1950	30	15000
November	7	948.143	159.000	5030.000	525	60	640
December	7	655.429	126.000	1670.000	1817	70	3200

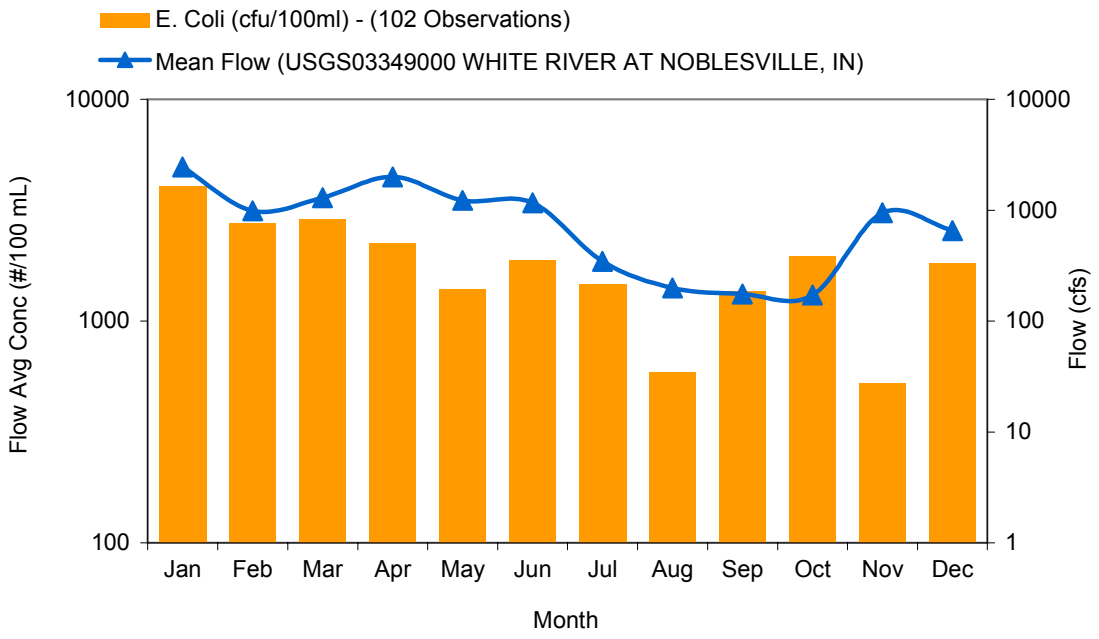

Figure 25. Comparison of seasonal variation of flow and *E. Coli* concentration for station WWU040-0004 (SR 13 Bridge at Perkinsville).

4.4 Comparison of *E. Coli* Data To Other Relevant Parameters

Many factors can influence the survival of *E. Coli* bacteria in the environment. These factors include water temperature, pH and settling out of bacterial particles and aggregates. The section below discusses the influence of each of these factors for the four stations with the most *E. Coli* data.

4.4.1 Temperature

Temperature has an inverse relationship with the survival of *E. Coli*, with survival typically decreasing as temperature increases. Temperature is considered the single most important modifier of pathogen decay rates in fresh water (USEPA, 2001).

Figure 26 shows that there does not appear to be a strong correlation between temperature and *E. Coli* concentrations for the WFWR data at WW010-0001. *E. Coli* concentrations have been observed to be high at both colder (0 to 6 ºC) and warmer temperatures (20 to 25 ºC). Similar results were observed at the other stations. Temperature dependence does not seem to be a driving force in *E. Coli* populations in the WFWR and therefore will be of limited importance during development of the TMDL.

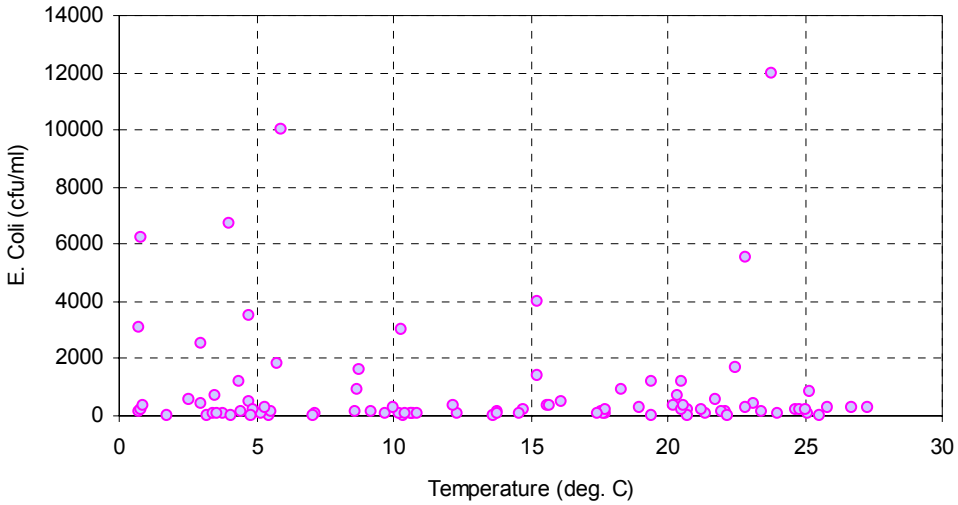

Figure 26. Correlation between *E. Coli* and temperature at station WW010-0001 (Memorial Dr. East edge of Muncie).

4.4.2 Sediment

Many studies have shown that there are often much higher numbers of indicator bacteria in sediments than in overlaying waters. Bacterial cells settle from the water column as discrete entities as well as larger aggregates of fecal material. Once settled, pathogens have an increased survival time in the sediments due to protection from sunlight and temperature.

To examine this issue for the WFWR data, *E. Coli* concentrations were plotted along with the corresponding turbidity values. Turbidity is a measure of the degree to which light is scattered by suspended particulate material in the water. It provides an estimate of the muddiness or cloudiness of the water due to clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds,

plankton, and microscopic organisms. Figure 27 shows a relatively strong correlation between turbidity and *E. Coli*. However, these data alone do not establish a cause and effect relationship between disturbed sediments and high *E. Coli* concentrations. For example, it is possible that the corresponding high turbidity and *E.Coli* concentrations could both be a function of another factor, such as wet weather. Both possibilities will be explored when modeling *E. Coli* concentrations in the stream.

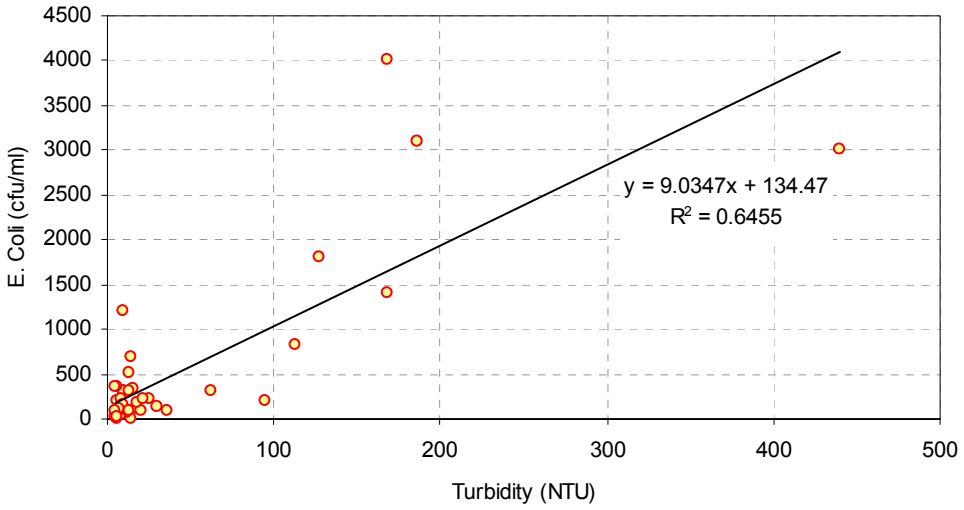

Figure 27. Correlation between *E. Coli* and turbidity at station WW010-0001 (Memorial Dr. East edge of Muncie).

4.4.3 pH

pH is a measure of the acidity of the water. It is measured on a scale from 0 (most acidic) to 14 (most alkaline), with 7 considered neutral. pH affects many chemical and biological processes in the water, such as the availability and toxicity of nutrients, metals, and other important compounds. Different organisms have different rages of pH within which they flourish. The largest varieties of aquatic animals prefer a range of 6.5 to 8.0. pH outside this range reduces the diversity of the stream. Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and wastewater discharges.

Figure 28 below shows that there is not a strong correlation between *E. Coli* and pH for the available data. High *E. Coli* counts have been observed at both low (~7.0) and high (~8.0) pH. Therefore pH dependence does not seem to be a driving force in *E. Coli* populations in the WFWR and will be of limited importance during development of the TMDL.

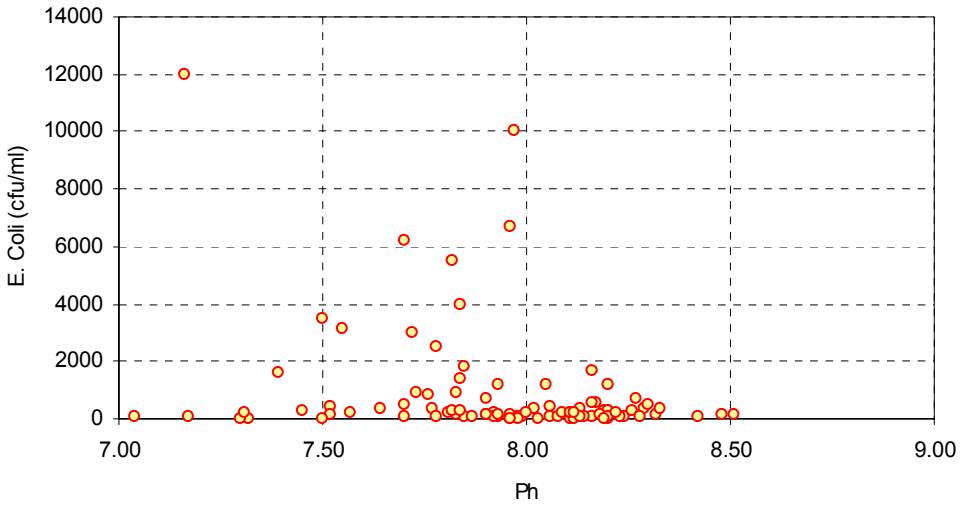

Figure 28. Correlation between *E. Coli* and pH at station WW010-0001 (Memorial Dr. East edge of Muncie).

5.0 EVALUATION OF DATA FOR TMDL DEVELOPMENT

The first step in the TMDL development process is to gather and assess all available data relevant to the watershed and the receiving water. The required data can be broken into two general types: point data and spatial data. The point data include water quality monitoring and discharge measurements, as well as basic meteorological data required by watershed and water quality models. Acquisition and processing of spatial or geographic data requires a fundamentally different approach from point data. Key spatial coverages for the WFWR watershed include land use/land cover, stream network, soils, and slopes. Additional spatial coverages that might be useful include digital orthoquads and cross-sectional data for watershed streams.

This report describes the progress that has been made to date in collecting and analyzing the available data for the WFWR watershed above the Hamilton-Marion County line. Additional data have been requested from various organizations within the watershed. Based upon a review of the currently available data and those data that are expected to be received, sufficient information exists to develop the TMDL. Enough flow and water quality data are available to setup and calibrate a dynamic watershed and water quality model. This model can be used to evaluate current loads of *E. Coli*, as well as the degree to which current loads must be reduced to achieve water quality standards. Furthermore, most of the data that will be used to develop the TMDL have been collected and processed by federal or state government agencies with established procedures for ensuring data quality and quality. The data are therefore considered to be acceptable.

Table 8. Summary of data needed for development of TMDL.

Data Type	Data	Source(s)	Available	Acceptable
Point Data	Stream flow	USGS	U	Yes
	Surface and ground water quality monitoring data	IDEM City of Muncie White River Watchers	U U °	Yes Yes Unknown
	Meteorological data within and in close proximity to the watershed	NCDC	U	Yes
	Discharge monitoring records from existing and proposed permitted facilities	IDEM	U	Yes
	Information on the location and characteristics of combined sewer overflows	City of Muncie City of Anderson	U °	Yes Unknown
Spatial Data	Land Use/Land Cover	MRLC Hamilton County Soil and Water Conservation District Madison County Council of Governments	U ° U	Yes Unknown Yes
	Stream network	USEPA National Hydrography Database	U	Yes
	Topography	Digital Elevation Model	U	Yes
	Soils	NRCS STATSGO Database	U	Yes
	Location of areas with failing/illicitly connected septic systems	County Health Departments	°	Unknown
	Digital Orthoquads	USGS	U	Yes

U = Obtained by Tetra Tech. ° = Requested but not yet received.

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APPENDIX A—SUMMARY OF THE PERIOD OF RECORD AND SAMPLING FREQUENCY AND RELEVANT STATISTICS FOR *E. COLI* MONITORING

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
WWU010-0001	White River	Memorial Dr, E Edge of Muncie	108	Jan-91	May-01	940	5	15000
WWU010-0007	W Fk White River	CR 762 E	1	Aug-96	Aug-96	90	90	90
WWU010-0019	W Fk White River	Broadway	5	Apr-01	May-01	318	110	820
WWU010-0022	Prairie Creek Res.	CR 300S at Windsor Pike and CR 475 E	4	Jun-01	Jun-01	38	9	86
WWU010-0023	W Fk White River	CR 700 E, S. of CR 175 S	4	Jun-01	Jun-01	298	194	488
WWU010-0024	W Fk White River	CR 275 S9 (Willow Sprs Rd) E. of Burlington Rd.	4	Jun-01	Jun-01	272	86	579
WWU010-0028	Mud Creek	CR 138 S, S. of SR 32	4	Jun-01	Jun-01	622	461	866
WWU020-0002	Buck Cr	CR 400 S	6	Feb-96	Jun-01	525	140	921
WWU020-0003	Bell Cr	CR 400 S	4	Feb-96	Jul-96	1510	70	5600
WWU020-0004	White River	Walnut St Bridge, N Side of Muncie	5	Apr-01	May-01	275	62	730
WWU020-0005	White River	Tiger Dr, CR Bridge N of Yorktown HS	103	Apr-91	May-01	2492	5	80000
WWU020-0008	Buck Cr	CR 700 S	2	Jun-01	Jun-01	923	866	980
WWU020-0012	W Fk White River	Jackson St	5	Apr-01	May-01	430	140	820
WWU020-0013	W Fk White River	Tillotson Ave	5	Apr-01	May-01	394	120	1000
WWU020-0014	W Fk White River	Kilgore Ave Muncie WWTP	5	Apr-01	May-01	289	1	1200
WWU020-0015	Buck Cr	Cornbread Rd	5	Apr-01	May-01	280	130	730
WWU020-0016	W Fk White River	Nebo Rd	5	Apr-01	May-01	610	170	1400
WWU020-0017	Buck Cr	Bell Creek Rd., S. of CR 200 S	2	Jun-01	Jun-01	518	488	548
WWU020-0018	Bell Creek	D/S of No-Name Creek, Jones Rd., W.of Proctor Rd., N. of CR 350 S	3	Jun-01	Jun-01	821	488	1203
WWU020-0019	Bell Creek	CR 700 S, E. of CR 600 W	3	Jun-01	Jun-01	518	488	548
WWU030-0002	White River	Madison-Delaware Co Line, E of Anderson	10	Apr-01	May-01	382	96	1100
WWU030-0003	White River	Anderson City Park Near Old Water Works Dam Site	104	Feb-91	May-01	1373	5	29000
WWU030-0004	W Fk White River	Yorktown WWTP, West St	6	Aug-96	May-01	111	3	600
WWU030-0009	Yorkprairie Cr	Burkmill Rd (175 S)	5	Apr-01	May-01	228	150	340
WWU030-0010	W Fk White River	CR 300 S	5	Apr-01	May-01	386	140	980
WWU030-0011	Shoemaker Cr	CR 400 S	5	Apr-01	May-01	544	130	1200

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
WWU030-0012	W Fk White River	CR 900 S	5	Apr-01	May-01	493	93	2000
WWU030-0013	Chesterfield Branch	Plum Street	5	Apr-01	May-01	630	310	920
WWU030-0014	W Fk White River	Chesterfield Road (CR 400 E)	5	Apr-01	May-01	484	130	1000
WWU030-0015	Turkey Creek	CR 150 N	5	Apr-01	May-01	308	120	610
WWU030-0019	W Fk White River	Rangeline Road (CR 200 E)	5	Apr-01	May-01	1569	76	6900
WWU040-0002	Killbuck Cr	CR 850 W	5	Feb-96	Nov-96	628	20	2400
WWU040-0003	Killbuck Cr	CR 200 E	6	Feb-96	Nov-96	703	5	3400
WWU040-0004	White River	SR 13 Bridge at Perkinsville	98	Jan-91	May-01	1112	5	15000
WWU040-0005	White River	Madison Ave Bridge	10	Apr-96	May-01	893	100	5000
WWU040-0006	Indian Cr	CR 200 N	1	Aug-96	Aug-96	60	60	60
WWU040-0007	Killbuck Cr	CR 450 E	1	Aug-96	Aug-96	400	400	400
WWU040-0012	Killbuck Cr	Grand Ave, Anderson	5	Apr-01	May-01	352	100	1000
WWU040-0013	Indian Cr	CR 200 N	5	Apr-01	May-01	864	310	2000
WWU040-0016	W Fk White River	Anderson Municipal STP, Effluent Sample, Gene Gustin Way	5	Apr-01	May-01	6	1	25
WWU050-0001	Pipe Cr	CR 100 E	6	Feb-96	Nov-96	360	10	1200
WWU050-0002	Mud Cr	CR 1100 N	5	Feb-96	Nov-96	134	10	220
WWU050-0003	Pipe Cr	SR 13	6	Feb-96	Nov-96	1495	20	4800
WWU050-0004	Pipe Cr	CR 200 W	1	Aug-96	Aug-96	400	400	400
WWU060-0001	Big Duck Cr	CR 1300 N, Fairground Rd, 4th Guardrail Support from SW, Measured on Outside Edge	6	Feb-96	Nov-96	350	10	1200
WWU060-0002	Duck Cr	CR 550 S, D/S Side, 6th Guardrail Support from SW Side	6	Feb-96	Nov-96	2913	80	8400
WWU060-0003	Duck Cr	SR 213, D/S Side, Past 4th Expansion Joint in Bridge Wall from SW	6	Feb-96	Nov-96	463	10	1600
WWU060-0004	Big Duck Cr	20th St	1	Aug-96	Aug-96	390	390	390
WWU070-0002	Stony Cr	Cumberland Rd, Gaging Station	6	Feb-96	Nov-96	478	5	1600
WWU070-0003	W Fk White River	Strawtown Ave	1	Aug-96	Aug-96	200	200	200
WWU080-0002	Cicero Cr	E 266th St, Arcadia	7	Feb-96	Aug-99	887	70	5000
WWU080-0003	Little Cicero Cr	E 266th St, D/S Side, 9th Guardrail Support from SW Side	6	Feb-96	Nov-96	611	5	1400
WWU080-0004	Cicero Cr	SR 38, Wire Weight Gage	6	Feb-96	Nov-96	103	5	380
WWU080-0006	Morse Reservoir	At Dam End of Reservoir- About 400 M U/S of Spillway	4	Jun-01	Jun-01	176	8	411

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
WWU080-0015	Hinkle Cr	E 216th St, E. of Hinkle Rd.	4	Jun-01	Jun-01	425	153	687
WWU080-0031	Cicero Creek,above Morse Resv	N. of 266th, E. of SR 19	4	Jun-01	Jun-01	639	172	1733
WWU080-0032	Little Cicero Creek	266th street, W. of Gwinn Rd (E73)	4	Jun-01	Jun-01	815	461	1733
WWU090-0003	W Fk White River	E 146th St, Noblesville Gage (317) 773-0975	6	Feb-96	Nov-96	355	30	1800
WWU090-0007	Cool Cr	Hazel Dell Parkway	6	Feb-96	Nov-96	87	30	150
WWU120-0009	Little Eagle Cr	W 146th St	1	Aug-96	Aug-96	200	200	200